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GB 1326696 A EP 0324508 A2 EP 0259683 A2
US 4977612 A

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(54) Radio communication network

(57) A mobile 20 operates within a radio communication network where there are a plurality of base stations 24, each allocated a radio channel 21, 22, 23. The mobile is informed of which channels are temporarily in use by a Short Information Message (SIM) which is broadcasted over the channels. The mobile scans all radio channels in its vicinity and determines the potential grade of service which each may provide. The mobile compares the channel availability information with its channel quality measurements to create a prioritized list of channels. The most favourable channel for communicating 21 is chosen, and the choice is relayed to base. The mobile regularly updates its knowledge of the status and potential grade of service of the radio channels in its locality. If the mobile's preferred channel becomes engaged, the mobile already knows which is the next best available channel.

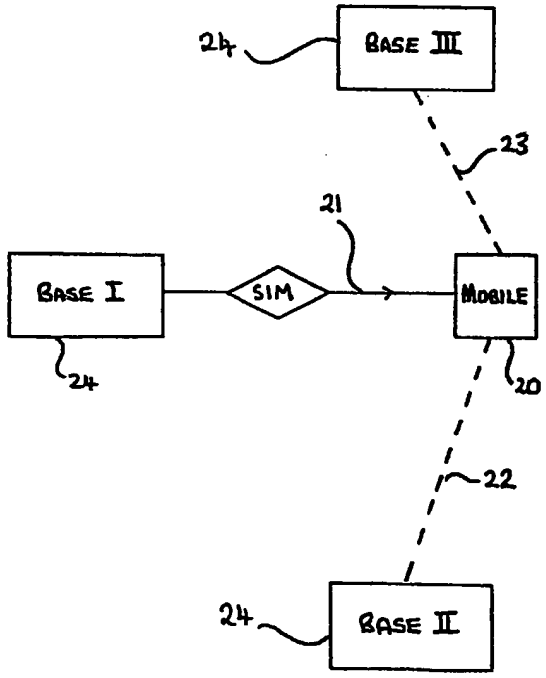

FIGURE 2.

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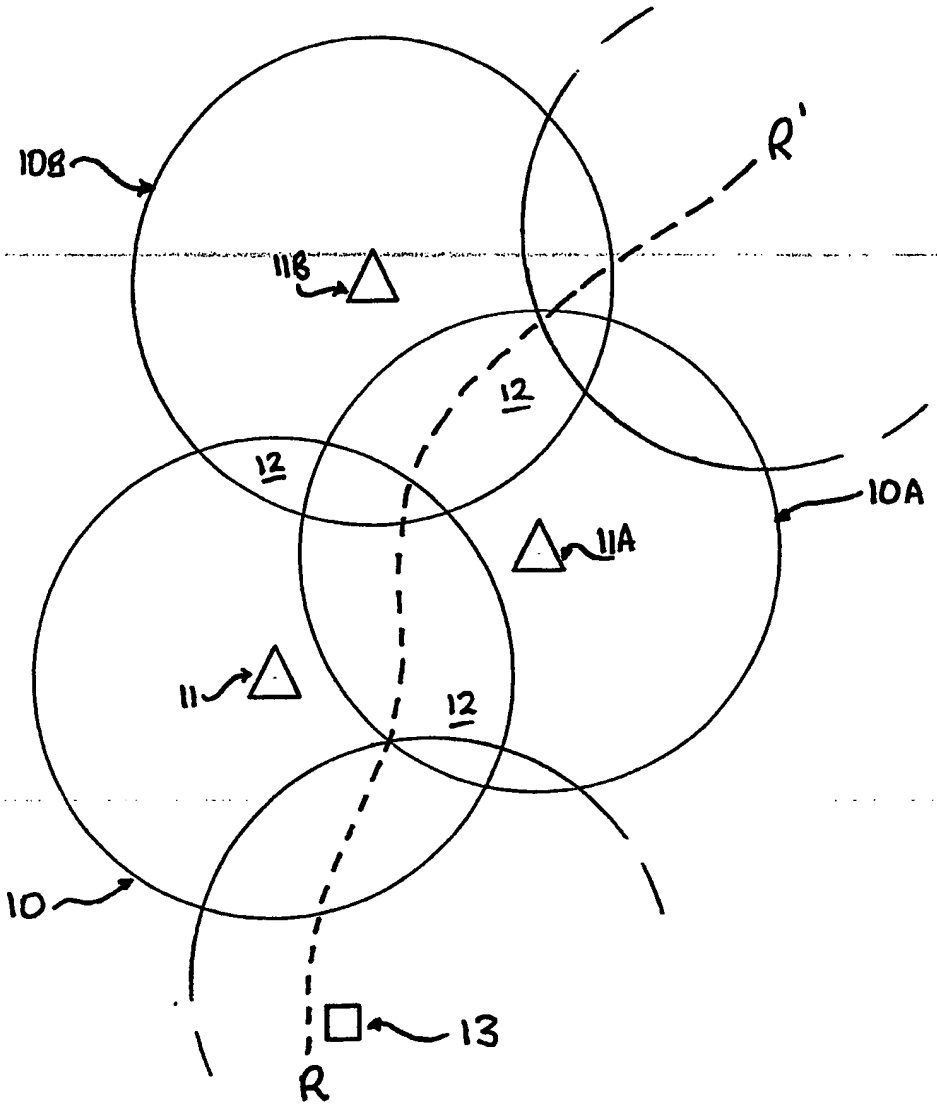

FIGURE 1

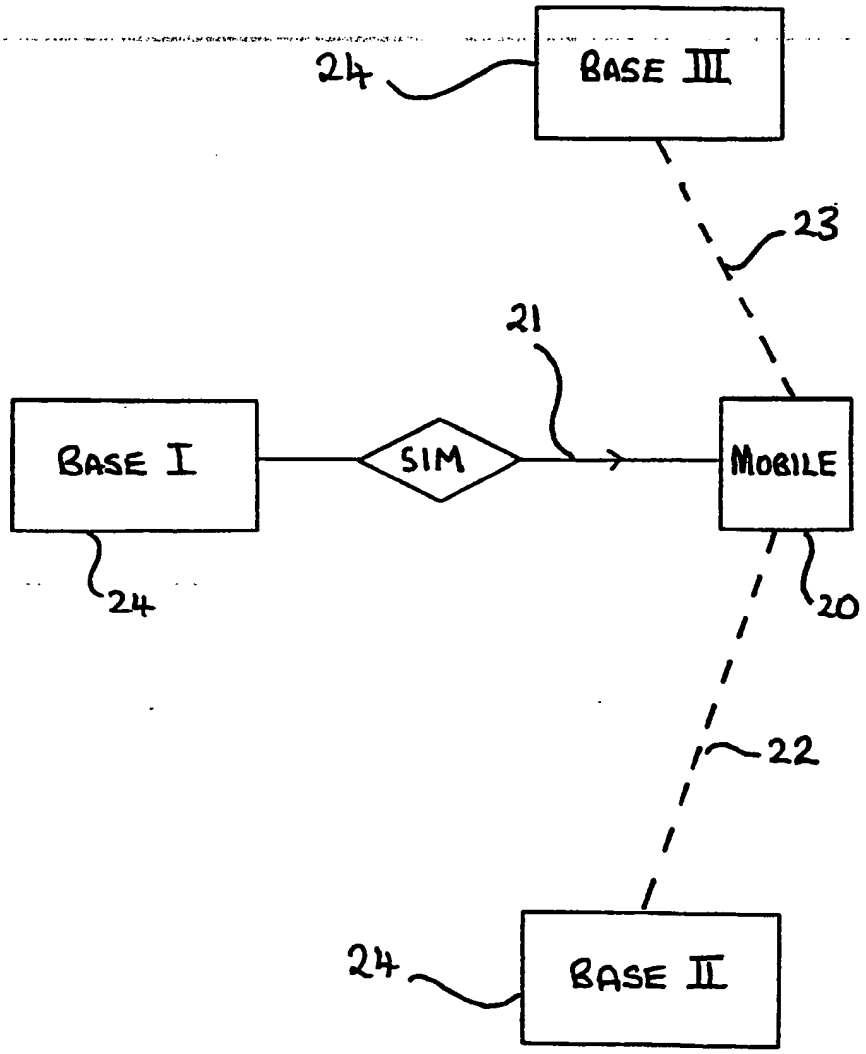

FIGURE 2.

RADIO COMMUNICATION SYSTEM

The present invention relates to a radio communication system, particularly but not exclusively to radio communication between mobiles and a network of base stations in the system.

A basic two-way communication system consists of a base station ("base") and one or more mobile units ("mobile"). The mobiles communicate with the base by radio transmitter/receiver sets, most often configured as transceivers. The number of mobiles which a base can serve depends, among other things, upon: the number of calls made by each unit; the duration of each call; and the number of distinct radio channels offered by the base. To obtain a reasonable traffic loading of any given channel, it has been found necessary to invoke the telephony principle of trunking. In a conventionally trunked radio system, it is considered desirable to instal at least three radio channels at the base station. In a privately owned network with only a small traffic requirement, offering this number of channels can be grossly wasteful for the vast majority of the time.

The principle of trunking of voice call channels has been widely applied to cellular mobile telephones, and also to public/private radio networks such as those according to U.K.Standard MPT 1327. In a basic system employing trunking, a given base station is equipped with a plurality of usable radio channels, one for control and several for traffic communication. A mobile desiring to make a call initiates an exchange of signalling messages via the control channel. In this manner, the mobile receives instructions to switch to the first available traffic channel installed at the base.

GB 2035011 discloses a method for establishing radio communication between mobiles through a base without the need for a separate radio signalling (control) channel. The base station, in this case, is merely a repeater. (A repeater intercepts and re-transmits to provide wider area communication coverage. Repeaters may also result in better quality communication between mobiles where direct access is impeded by buildings or the lay of

the land). Each repeater has a plurality of channels, for example channels 1 to 5. When a mobile wishes to communicate with one or other users in a predetermined group, the mobile is placed in call originate mode causing it to scan the assigned repeater channels to locate a clear channel. Once a clear channel is found, for example channel 3, the mobile transmits a "busy" signal on that channel to warn off other potential users. Once the repeater acknowledges the busy signal, channel 3 becomes dedicated to the use of the mobile until it has finished its communication. The exchange of signals is very basic; and the mobile's assessment of a radio channel is strictly limited, being of no assisstance beyond ascertaining whether it is free or busy.

A base station can only establish contact with a mobile within a certain range, the magnitude of which is proportional to the strength of the transmitted signal. If the system is to operate over a large area, for example several English counties, then there are two theoretical possibilities for providing coverage. The first option is to use an extremely powerful base station to blanket the service area; and the second is to establish a network of bases, with each base transmitting over a shorter range. The first solution is impractical; whereas the second, which creates a cellular radio system, offers considerable flexibility and is the solution adopted in practice.

Reference should now be made to Figure 1 which shows schematically part of a typical cellular radio system. In a cellular system, the area to be served is sub-divided into a network of coverage areas or cells 10, 10A, 10B. Each cell contains a low powered base station 11, 11A, 11B which is assigned a set of channels of predetermined frequency. For the system to operate effectively, every geographic point in the service area must be within range of at least one base. This inevitably means that, due to statistical fluctuations in a radio path, a mobile in certain regions is capable of interfacing with more than one base. For example, often between 30% and 45% of an operational area can be unintentionally well served by more than one base. To prevent interference in the overlapped regions 12, adjacent bases must be assigned channels of different frequencies. By limiting the power level of the base

transmitters, channel frequencies may be re-used in non-adjacent cells. As a mobile 13 moves through the service area along route RR', the mobile must tune to the channel frequencies offered by a base within range of its immediate vicinity.

EP 0042529 relates to trunking in connection with a cellular system. The main thrust of the patent is to tackle the problem of the large number of radio channels to be scanned by a mobile, whilst allowing a mobile which normally operates in a first cell (cell A) to interface with a base in a neighbouring cell (cell B). Suppose channels 1 to 5 are assigned to the base in cell A, and channels 6 to 10 in cell B. As the mobile enters the neighbouring cell, the mobile is told which cell to operate in. When a given cell is selected, only the channels associated with that cell are scanned. Consequently, no time is wasted in scanning channels not utilised in a particular locality. Hence, the mobile has the flexibility to change its operating cell upon arrival in the neighbouring cell. "Hard switching" from trunking in channels 1 to 5 to trunking in channels 6 to 10 obviates the need for complex re-programming of the channel frequencies scanned by the mobile. However, hard switching prevents the mobile from taking advantage of those regions which are served by more than one base station. The inability of the mobile to make use of channels provided by a base station in a neighbouring cell, even though the channels may be capable of providing an adequate grade of service, is wasteful and undesirable.

In a preferred embodiment of the present invention a mobile operating within a radio communication network scans a plurality of radio channels offered by base stations within its vicinity and selects one channel for communicating by assessing which channel is capable of providing the best grade of service.

In accordance with the present invention, in a first aspect, there is provided a radio communication system comprising a plurality of base stations and of mobile units operating within the system, each base station having at least one radio channel for communicating with the mobiles, with adjacent base stations having radio channels of different frequency, and each mobile having means for scanning the radio channels, means for receiving

a message sent over the radio channels, the message comprising information as to the availability of the radio channels, means for measuring the strength and/or the quality of a signal transmitted by a base station on one of the radio channels, means for comparing the channel availability information with the channel strength and/or quality data and means for selecting a radio channel for communication in dependence on the result of the comparison.

If the system is to operate effectively, the availability information broadcast to the mobiles must be as up to date as possible and each mobile must be capable of determining its preferred channel extremely rapidly.

Preferably, the mobile selects one of the available radio channels, the selected channel is for receiving instructions from a base station, and interleaves the scanning of the selected radio channel with the scanning of other radio channels in the system. It is then possible for the base station to initiate a call with the mobile.

Preferably the mobile continues with the selected radio channel until differential quality measurements indicate that the selected radio channel is no longer capable of providing acceptable service. Most multi-base station radio systems have an automatic process for "handing over" or "re-registering" a mobile. These normally work on the basis of received radio signal strength. If the strength drops below a certain level, indicative of a channel on the threshold of adequacy, the mobile changes to another base station which theoretically will offer better service. However, in a cellular re-use system, the limit of performance is typically not general background noise which can be alleviated by ensuring an adequate radio signal strength threshold. Instead the performance limit is interference from co-channel unwanted signals from bases re-using the same channel frequency.

In a preferred form, the base station transmits information to the mobile over the selected channel, which the mobile can use to limit the number of channels it scans.

The large volume of information received by the mobile may be sent via a sophisticated digital signalling technique.

In accordance with the present invention, according to a second aspect, there is provided a radio communication system comprising a base station and a plurality of mobile units operating within the system, the base station having at least one radio channel for communicating with the mobile units, and having means for periodically transmitting on each radio channel a message comprising channel availability information, each mobile unit having means for selecting a radio channel for communication in dependence on receiveed channel availability information.

An embodiment of the present invention is now described in more detail, by way of example, with reference to the accompanying drawing in which:

Figure 1 shows schematically the overlapping cells within a cellular radio system; and

Figure 2 shows schematically a radio communication system embodying the invention.

A trunked radio system according to the invention comprises a plurality of base stations, spread throughout the service area, and a large number of mobile units for example 1,000 units. (The term radio is used in a generic sense, as applied to methods of signalling through space, without connecting wires, by means of electromagnetic waves generated by high frequency alternating currents). Control of the system is exercised by the mobiles, and not by the system equipment. In order to assert such control, it is necessary for the mobiles to be highly intelligent and for the system to regularly broadcast meaningful information to the various mobiles.

The mobiles in the system operate in a background channel scanning regime. This means that when they are not actively involved in actually communicating (usually the vast majority of the time), the mobiles are continuously scanning all detectable channels to determine which would give the best service at that point in time, should the need to initiate a call arise. At any particular moment, a mobile has pre-selected an available channel (the selected channel) and informed the base of its decision. The selected channel then becomes the operational channel should the base need to contact the mobile.

The background scanning pattern of a mobile 20 is interleaved. In other words, the mobile 20 scans its selected channel 21, then scans a first alternative channel (channel A) 22, and returns to the selected channel before scanning a second alternative channel (channel B) 23. The selected channel, channel A and channel B may all be affiliated to different base stations 24. The presence of the mobile on the selected channel is synchronised either with a timing signal sent to it as part of a regular broadcast called the mobile information message (MIM), or by reference to a synchronised clock. This means that the mobile is always tuned to its channel when the base offering that channel may be in a position to send a message.

A mobile does not necessarily scan all the radio channels in the system. For example, in a large service area, a mobile may not be able to receive even a poor level of service from typically 50% to 75% of the total channels in the system at any particular moment. Therefore, the mobile receives a preferred list of channels to be scanned, the list being transmitted by the base station as part of the MIM. The list specifically includes all the channels of the base stations in the immediate locality of the mobile. Hence, the mobile saves time by scanning only those channels which could conceivably offer good service, and ignoring all the channels of the base stations in the system not listed in the MIM. Typically, the list would include between 25% and 50% of all the channels available in the system.

A mobile assesses the quality of each channel on the basis of received signal strength (RSS) and quality of data, for example the bit error ratio (BER). If a radio channel is instantaneously busy at the time when the mobile tunes to it, then the mobile will simply measure the signal present and categorise this, generating no additional traffic in order to support this signalling. If the channel is not in use when the mobile tunes to it, then the mobile will send an enquiry message which will be responded to by the base station managing the channel. The response sent by the base station enables the mobile to assess the suitability of the channel, and to allow comparisons to be made with other channels.

The mobile continues to monitor its selected channel until the channel is considered to no longer be capable of offering adequate service. One method of determining the point when service on the selected channel becomes unacceptable is for the mobile to conduct differential quality measurements. In a cellular system, radio channel frequencies are re-used in non-adjacent cells. Initially, a mobile selects a suitable channel of frequency Z operated by a first base station in a first cell. In a non-contiguous cell, a different base station will also be assigned a channel of frequency Z. When in the first cell monitoring frequency Z, the mobile will detect a strong signal from the first base as well as a much weaker "interference" signal from the other base station. Therefore the mobile can measure the BER and RSS of the selected channel against those of the potential interference channel. If the quality differential becomes too small, the mobile will automatically change its selected channel for one capable of giving an improved service.

Measuring quality differentially means that a mobile uses its selected channel right up to the limit of acceptable service. The mobile is therefore able to utilize a channel where service is fine in practice but theoretically questionable.

The signalling so far described gives the mobile a prioritized list of channels which would offer a suitable grade of service at the mobile's current location. However nothing has yet been said of the instantaneous free/busy condition of each channel.

A short information message (SIM), similar to the MIM, is broadcast simultaneously and very frequently on all channels. Both the SIM and the MIM may be sent via sophisticated digital signalling techniques. The SIM carries an indication of the status of each channel in the network, for example "channel A, base 1 - in voice use, channel B, base 2 - not in voice use, channel A, base 3 - not in voice use". The status of each channel is updated regularly, preferably inbetween each SIM broadcast, to allow a revised channel status list to be produced in time before the next broadcast. Any mobile tuned to any of the channels at the time of the SIM broadcast can assimilate the

data contained therein. The mobile uses the data to amend continuously its knowledge as to the highest quality local channel which is currently free.

If the mobile learns from the SIM that its selected channel is temporarily busy, the mobile will switch to the next best available channel for communicating. This temporary change of channel selection is relayed to the base station. As soon as the mobile is informed via the SIM that the preferred channel is no longer busy, the mobile will revert to its former channel so long as this channel is still capable of providing a good grade of service. If all possible channels in the vicinity of the mobile are engaged at a given time, the mobile will not be able to establish contact with a base. Instead, the mobile enters a stand-by mode and must wait for a channel to become available.

The sophisticated information gathering on the part of the mobile means that when a call is to be placed through the network, the mobile already knows the best available channel to choose for the communication which reduces the inherent delay between setting up a voice call and actually communicating. The mobile is capable of choosing the best radio channel irrespective of which base station controls that channel.

The radio network system designer can choose to take advantage of the benefits of the invention in one of several distinct ways.

The designer may simply employ the invention to utilise the overlaps in coverage between adjacent radio base stations. If the total number of radio channels installed and the number of bases is kept the same, then the overlapping areas will have a higher number of radio channels being trunked together. Consequently, the customer will be provided with a better average grade of service. Alternatively, where the degree of overlap in coverage is high, it will be possible to reduce the number of radio channels and/or the number of base stations, whilst retaining the same grade of service achieved by a conventionally trunked system with the former number of channels and bases. This saving will be most marked in the lower traffic areas where a reduction in the per-locality number of channels from, for example, three channels to two channels may be achievable.

The invention allows the radio network system designer to adopt a better approach to his radio network design. Using the invention, the designer can opt for a large number of different radio base stations, each equipped with only one radio channel. Each base can be relatively poor in radio terms, for example transmitting over a restricted range, but because of the large numbers of bases involved, the result is a relatively even radio illumination throughout the service area. The illumination is far more even than can be achieved with a conventionally trunked network, since in the conventional network it is necessary to co-locate as many channels as possible at each of as few radio bases as possible in order to achieve the necessary trunking "gains".

Some of the base stations used by the designer may transmit over a very restricted range, which of course means that the re-use exclusion area is small. Accordingly, more intensive re-use of radio frequency allocations within a geographical service area is facilitated. Intensive re-use yields a network of higher capacity than is possible using a conventionally trunked network with the same number of highly valuable radio frequency allocations.

CLAIMS:

1. A radio communication system comprising a plurality of base stations and of mobile units operating within the system, each base station having at least one radio channel for communicating with the mobiles, with adjacent base stations having radio channels of different frequency, and each mobile unit having means for scanning the radio channels, means for receiving a message sent over the radio channels, the message comprising information as to the availability of the radio channels, means for measuring the strength and/or the quality of a signal transmitted by a base station on one of the radio channels, means for comparing the channel availability information with the channel strength and/or quality data and means for selecting a radio channel for communication in dependence on the result of the comparison.

2. A radio communication system according to claim 1 in which the signal measured for strength and/or quality by the mobile unit is transmitted by the base station in response to an enquiry message sent by the mobile unit.

3. A radio communication system according to claim 1 or 2 in which the mobile unit selects one of the available radio channels for receiving instructions from a base station and interleaves normal reception of the selected radio channel with the scanning of other radio channels in the system.

4. A radio communication system according to claim 3 in which the scanning of the radio channels by the mobile unit is synchronized by a timing signal transmitted on the selected radio channel.

5. A radio communication system according to claim 3 or 4 in which the mobile unit continues with the selected radio channel until differential quality measurements indicate that the selected radio channel is no longer capable of providing

acceptable service.

6. A radio communication system according to any of claims 3 to 5 in which the number of radio channels to be scanned by the mobile unit is limited by information received on the selected radio channel and transmitted by the base station.

7. A radio communication system according to claim 6 in which the number of radio channels scanned by the mobile unit is typically between 25% and 50% of the total number of radio channels in the system.

8. A radio communication system substantially as hereinbefore described.

9. A mobile unit for use in a radio communication network comprising means for receiving messages sent over radio channels within the network, the messages including information as to the availability of each channel, means for scanning radio channels within the network, means for measuring the strength and/or the quality of a signal transmitted on each radio channel, means for comparing the channel availability information and the signal strength and/or quality data, and means for selecting radio channel for communication in dependence on the result of the comparison.

10. A radio communication system comprising a base station and a plurality of mobile units operating within the system, the base station having at least one radio channel for communicating with the mobile units, and having means for periodically transmitting on each radio channel a message comprising channel availability information, each mobile unit having means for selecting a radio channel for communication in dependence on received channel availability information.

11. A mobile unit for use in a radio communication system comprising means for receiving a message sent over each radio channel within the system, the message including information as

to the availability of the radio channels, and means for selecting a radio channel for communication in dependence on the channel availability information.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

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Search Examiner
N W HALL

Databases (see over)

(i) UK Patent Office

(ii) ON-LINE: WPI

Date of Search
14 JULY 1993

Documents considered relevant following a search in respect of claims 1-9

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0324508 A2 (SUMITOMO) see page 4, lines 22-24; page 3 lines 20-23	1-9
X	EP 0259683 A2 (NEC) see abstract	1-9
X	US 4977612 (MOTOROLA) see abstract	1-9
A	GB 1326696 (CIT) see abstract	

.Category	Identity of document and relevant passages — 14 —	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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